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Interactions between earthworms, soil organic matter and microflora in an African savanna soil

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Summary :

Young *Millsonia anomala* have been grown in a poor soil added with 25, 50, 75... 225, and 250 mg of dry hydrosoluble extract from savanna graminean leaves. Soil ingestion decreased regularly from 23.6 ± 1.6 to 10.5 ± 1.3 g dry soil/g fresh weight/day. Microbial activity was increased from the control to the concentration 75, then inhibited, first strongly from 100 to 150, then slightly in the following series.

Key words : tropical earthworms, microbial activity, watersoluble organic matter, African savanna.

I. Introduction

Millsonia anomala is an endogeic mesohumic earthworm whose populations are abundant in the moist derived savannas of the Ivory Coast. These worms daily ingest from 5 to 36 g dry soil/g fresh weight according to their individual weight, soil temperature and moisture and also the characteristics of organic matter (LAVELLE, 1975).

Soil ingestion varies with depth of earthworm distribution : it is maximal from -2 to -10 cm, decreases slightly towards the soil surface (0-1 cm) and at 10-25 cm then sharply in the deeper horizons (30-40 cm) (LAVELLE *et al.*, 1980). In other respects, the soil ingestion rate and the growth rate of earthworms fed with a poor soil enriched with different kinds of composts showed marked variations according to the nature of the compost (from grass leaves or roots, whether kept under aerobic or anaerobic conditions).

These results indicate that the quality of the soil organic matter is a regulating factor of soil ingestion by the earthworm. Also, we found that the casts may have a lower or higher respiratory activity than the non-ingested soil, depending on the nature of the added organic matter.

The above results suggest the following hypotheses. Earthworms which have limited enzymatic equipments feed preferentially on simple organic compounds, mostly watersoluble ones. When the concentrations are high, they extract directly these elements from the soil. Their relation to soil microflora turns from neutralism to inhibition when concentrations lessen, increasing the potential competition between the earthworm and the microflora of its proper gut. When the soil is even poorer, earthworms could increase in their guts the activity of a microflora that could transform complex organic compounds into simpler hydrosoluble ones, more easily assimilated.

Experimental cultures were carried out in order to test the importance of watersoluble organic matter contents on the soil ingestion of the earthworm and the respiratory activity of the casts as compared to the non-ingested soil.

II. Methods

Young *M. anomala* were grown in a soil with low organic contents taken from the stratum 10-25 cm of a shrub savanna, moistened up to pF 2.5 and supplemented with increasing doses of hydrosoluble extracts from savanna graminean leaves. The extract was prepared by mixing 200 g of dry powder with 2 l of water at 60° C for one hour. After filtering the solution, an aliquot part was oven dried at 80° C in order to measure the dry matter contents, 18 % of the dry weight of the leaves in this experiment.

Ten sets of cultures were designed : H25, H50, H75... until H250 in which were respectively added 25, 50, 75... 250 mg dry hydrosoluble organic matter per 100 g dry soil. Control soil contents were 20 mg/100 g.

Each set included five Petri dishes (10 cm in diameter, 1.5 cm high) with two recently born worms in each dish. Every 3 or 4 days, the soil was changed, the worms weighed and their ingestion measured. The culture method is as described in LAVELLE (1975). Casts and non-ingested soil were air dried and kept for further chemical and respirometric studies. Cultures were kept for 28 days.

Respiratory activity was measured by the Lundegardh method as indicated by RASHID & SCHAEFER (1978). The measured values correspond to 48 days of incubation.

III. Results

1. Differences of the hydrosoluble organic contents in culture soil and casts

The graminean hydrosoluble extract contains simple sugars, amino and fatty acids and, thus, constitutes a high energy source and accessible substrate. When added in solution to the soil, it is completely dispersed and rapidly attacked by the microflora, so that the concentration decreases rapidly while an important microbial activity develops. Beyond a concentration of 75 mg/g, high development of fungal mycelia was observed after a few days. Sometimes, fungal growth affected the experiment; part of the variation in the data may have been due to this. SENAPATI (1980) showed that earthworms may die in great numbers from fungal infections and, generally speaking, we have always observed an increased mortality in cultures invaded by fungi.

Watersoluble components disappeared very quickly in the culture soil : after three days, their concentration had decreased from 87.4 (in H150) to 97.3 % (H125) and this decrease was significantly correlated with the initial concentration ($\alpha < 0.01$) (Fig. 1).

The results of a set of control analyses (total carbon and nitrogen contents and pH) showed that this watersoluble organic matter has been really consumed by the microorganisms and the earthworm rather than being insolubilised in the form of stable organomineral compounds (DUBREUIL & ZAIDI, 1980). The results can be explained by the low clay contents of the soil (5 % on average) and its slight acidity (TOUTAIN, 1974).

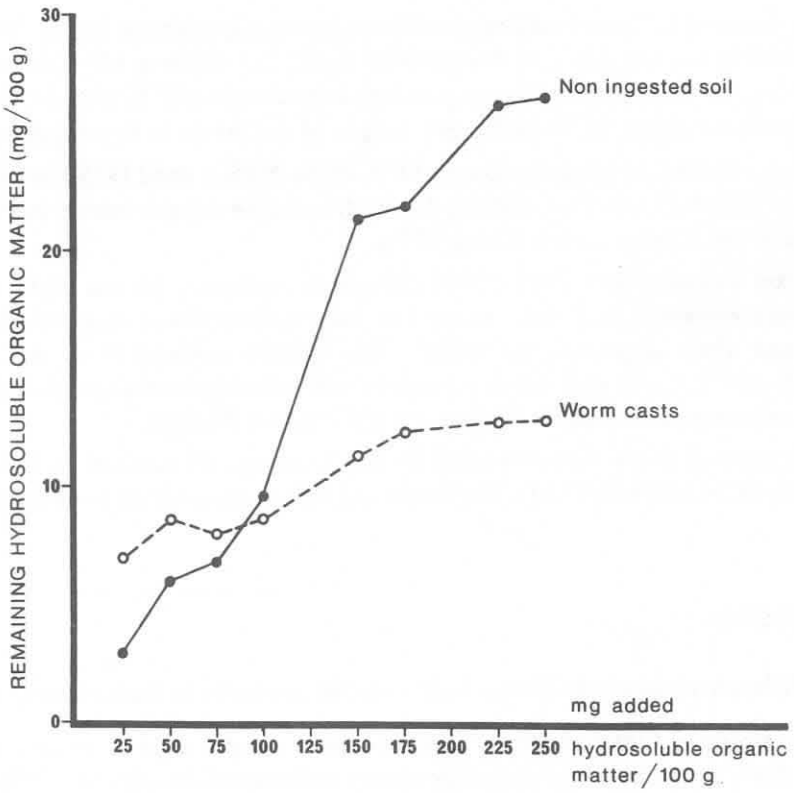

Figure 1 Hydrosoluble organic contents of worm casts and non-ingested soil as a function of initial hydrosoluble contents.

The residual concentration of water-soluble organic matter was different in the casts and in the non-ingested soil : it was higher in the casts when the culture soil contents were low (H25 to H75) and lower with high initial concentrations (H100 to H250) (Fig. 1).

2. Soil ingestion and microbial activity in the casts

Soil ingestion decreased in a highly significant way from the series H25 (23.6 g dry soil/g fresh weight/day) to H250 (10.5 g/g f.wt./d) (Fig. 2).

The microbial activity of the casts also showed interesting variations as compared to the activity of the non-ingested soil. In the control and series H25 to H75 with low contents of watersoluble extract, the casts have a respiratory activity 12 to 60 % greater than the non-ingested soil. From H100 onwards the result was suddenly inversed as the respiratory activity of cast decreased, first greatly (-62.9 % in H100), and then less so in the soils with the highest watersoluble contents.

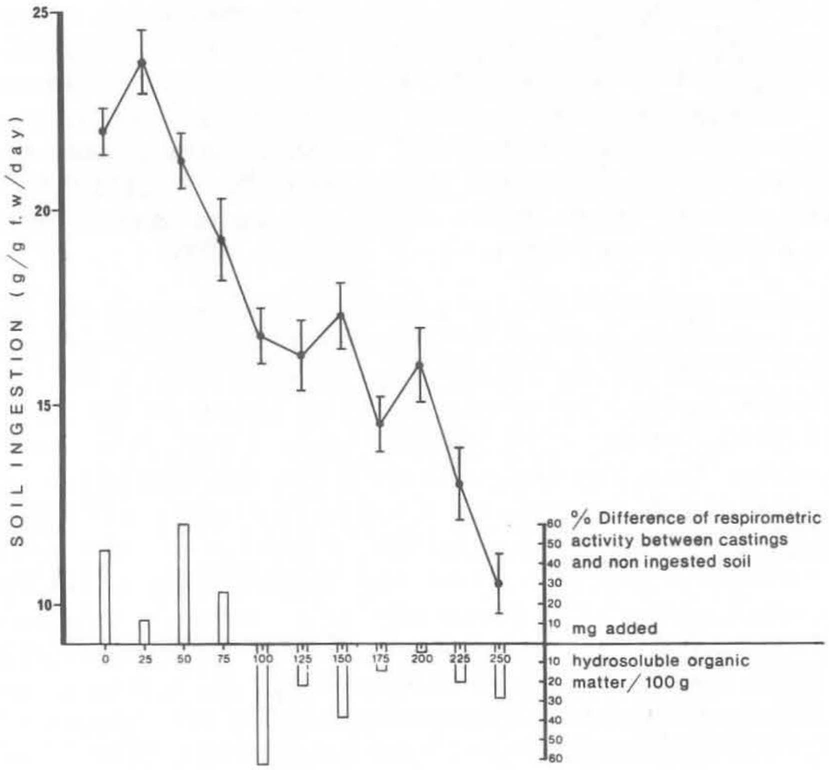

Figure 2 Variations of soil ingestion by earthworms (points) and differences of respirometric activity between castings and non-ingested soil (blocks) as a function of initial hydrosoluble contents.

Despite variations due to the disturbing effect of fungal proliferations in some cultures, two, perhaps three, phases can be distinguished along these series of soils with increasing water soluble contents :

— in the soils with low contents, the activation of microflora is clear and varies from + 12.3 to + 62.2 %;

— beyond a threshold between the concentrations H75 and H100, the relation reverses as the microbial activity is sharply inhibited : -62.9 % in H100 and still -38.5 % in H150;

— in soils with high watersoluble contents, this inhibition still exists but is less important with a value of around -20 %.

IV. Discussion

Two main points emerge from our study which enlighten the hypothesis set out in the introduction.

First, the soil ingestion rates of the earthworms appeared to be inversely proportional to the watersoluble contents of the soil. These high energy compounds may play a regulating role in the amount of soil taken by the worm or, in other words, in the allocation of energy to feeding. This would have implications for earthworm growth. In an independent study, the daily growth rate of earthworms showed a slight decrease from the serie H150 in which the mean value was 4.2 % to H250 (2.75 %). However, such differences did not prove to be significant, as a result of the irregularity of this growth, a normal feature in earthworms (LAVELLE, 1978).

Another important result is the inverse relationship between final watersoluble contents in the non-ingested soil and the casts when the initially added concentration increases from 75 to 100 mg/100 g soil. When the worms fed on a poor soil, their casts had greater watersoluble contents and respiratory activity; on the contrary, in a soil with a high watersoluble contents, the casts contained less and their respiratory activity was lower. These facts support our initial hypothesis that when the soil has a low watersoluble content, the earthworm stimulates the activity of microorganisms in its gut and is able to release such simple substances from more complex ones. This might result in the higher respiratory activity and watersoluble contents measured in the casts. When the soil has higher watersoluble contents, the activation of this microflora no longer exists and then only stands out the inhibition of the microorganisms consuming simple compounds. Such an inhibition would be, in its turn, progressively removed as the watersoluble soil contents increase. The lower inhibition observed in the series H175 to H250 might be part of such a trend. So would be reached the neutral situation described in a previous work (LAVELLE *et al.*, 1980) in which there is nor competition nor symbiosis between the earthworm and its microflora.

Some concordant results can be found in the work of de PUYTORAC & MAURET (1956) that showed a decrease of water-soluble substances in the posterior gut of *Allolobophora savygnii*. BRUSEWITZ (1956) observed a multiplication of microorganisms in the casts only when the worms were fed on coriaceous plant debris. SATCHELL & LOWE (1963) showed that a relation existed between the feeding preferences of some Lumbricidae and the watersoluble contents of the litter.

These results emphasize the role of the watersoluble fraction of the soil organic matter as a regulating factor of the mechanical activity of earthworms, through their soil ingestion. This fraction also determines the intensity and quality of the microbial activity in their guts, directly and above all indirectly through the activities of earthworms. This mechanism would be of great importance for recycling of organic and mineral matter in the whole ecosystem as the earthworm communities ingest up to 1200 t dry soil/ha/year in these savannas (LAVELLE, 1978).

The last important feature is the extreme robustness of these mechanisms : the difference of activity created by the earthworm inside its proper gut can still be measured long after faeces have been deposited in the soil. This is clearly shown in our measurements made during 48 days with casts that had been previously air dried and then remoistened.

Many questions however remain. In particular, it would be necessary to study in detail the evolution of microbial communities during the intestinal transit and investigate how earthworms influence their composition and activity : effects of pH variations (VAN GANSEN, 1962; JEUNIAUX, 1969), production of a mucus whose composition and quantity could vary, as strongly suggested by the work of LAVELLE *et al.* (1983) or any other physico-chemical process.

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References

BRUSEWITZ (G.), 1959. — Untersuchungen über den Einfluss des Regenwurms am Zahl Art und Leistungen von Mikroorganismen im Boden. — *Arch. Mikrobiol.*, **33** : 52-82.

DUBREUIL (S.) & ZAIDI (Z.), 1980. — *Interactions trophiques et métaboliques entre les microbiocénoses et les populations de vers de terre d'un sol ferrallitique de la savane guinéenne.* — DEA, Paris-Sud, 47 p.

JEUNIAUX (Ch.), 1969. — Nutrition and Digestion. *In* M. FLORKIN & B.T. SCHEER (Eds.), *Chemical Zoology.* — Academic Press, New York, **4** : 69-91.

LAVELLE (P.), 1975. — Consommation annuelle de terre par une population naturelle de vers de terre (*Millsonia anomala* Omodeo, Acanthodrilidae-Oligochètes). dans la savane de Lamto (Côte d'Ivoire). — *Rev. Ecol. Biol. Sol.*, **12** : 11-24.

LAVELLE (P.), 1978. — *Les vers de terre de la savane de Lamto (Côte d'Ivoire) : peuplements, populations et fonctions dans l'écosystème.* — Publ. Lab. Zool. E.N.S., **12** : 301 p.

LAVELLE (P.), SOW (B.) & SCHAEFER (R.), 1980. — The geophagous earthworms community in the Lamto savanna (Ivory Coast); niche partitioning and utilization of soil nutritive resources. *In* D. DINDAL (Ed.), *Soil Biology as related to Land Use Practices.* — EPA Washington, D.C. : 653-672.

LAVELLE (P.), KANYONYO (J.) & RANGEL (P.), 1983. — Intestinal mucus production by two species of tropical earthworms : *Millsonia lamtoiana* (Megascolecidae) and *Ponthoscolex corethrurus* (Glossoscolecidae). *In* Ph. LEBRUN, H.M. ANDRÉ, A. DEMEDTS, C. GRÉGOIRE-WIBO & G. WAUTHY (Eds.), *New Trends in Soil Biology.* — Imprimeur DIEU-BRICHART, Ottignies-Louvain-la-Neuve : 395-400.

PUYTORAC (P. de) & MAURET (P.), 1956. — Détermination de certaines des conditions écologiques propres aux différents ciliés parasites du tube digestif *d'Allolobophora savygnyi* G. et H. (Oligochète). — *Bull. Biol. de la France et de la Belgique*, TXC, **2** : 1-20.

RASHID (G.H.) & SCHAEFER (R.), 1978. — Observations sur l'interdépendance, dans sa variété saisonnière, entre l'économie des ressources énergétiques et les activités microbiennes dans une aire topographique de sols. — *103° Congr. national des sociétés savantes,* Nancy, Sciences (IV) : 243-256.

SATCHELL (J.E.) & LOWE (D.G.), 1967. — Selection of leaf litter by *Lumbricus terrestris. In* O. GRAFF & J.E. SATCHELL (Eds.), *Progress in soil Biology.* — Vieweg & Sohn, Braunschweig : 102-119.

SENAPATI (B.K.), 1980. — *Aspects of ecophysiological studies on tropical earthworms (Distribution, Population dynamics, Production, Energetics and their role in the decomposition process).* — PH.D., Sambalpur, Univ. INDE, 154 p.

TOUTAIN (F.), 1974. — *Etude écologique de l'humification dans les hêtraies acidiphiles* ». — Thèse doctorat, Nancy, 123 p.

VAN GANSEN (P.S.), 1962. — Structures and functions of the digestive tract of the lumbricid *Eisenia foetida* Savigny. *Journal of Microscopy* I. 363 p.

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